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Large Monolithic Mirror (LMM) for TPF

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NASA Tech Days

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LMM Study Overview

- **Objective of LMM Study**
  - Determine the feasibility of building a 4x10 meter mirror to chronographic TPF requirements
- **Approach**
  - Create an LMM concept design traceable to TPF-like requirements and consistent with known manufacturing and control approaches (i.e. don't baseline miracles)
    - Define initial requirements and assumptions
    - Layout a PMA concept
    - Outline a manufacturing approach
    - Perform first order trades to arrive at an LMM concept design
    - Evaluate performance and manufacturability of the concept to access risk and degrees of difficulty

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LMM Initial Requirements

- **Kodak worked with BATC in the fall of '02 to define a preliminary set of design and performance requirements**

Mirror Requirement	Description
Aperture	
Shape	Approximately elliptical
Length	10m along major axis
Area	$30m^2$
Areal Density (Mirror Only)	≤ 25 kg/m^2
Optical Surface	
Form	Off-axis parabola (k = -1)
Parent diameter	11m
Offset distance	2.11m (center of parent to center of aperture)
Radius of curvature	29.8m
Total surface error	$\leq$ 10nm rms (after actuator correction)
- 0-3 cycles/aperture	$\leq$ 8nm rms (after actuator correction)
- 3-10,000 cycles/aperture	$\leq$ 5nm rms (after actuator correction)
- >10,000 cycles/aperture	$\leq$ 1.5nm rms (after actuator correction)
Environment	
Launch loads	10-g quasi-static axial & lateral combined
Thermal	
- Operating temperature	20 deg C
- Isothermal DT	+/- 0.5 deg C
- Axial gradient	0.5 deg C

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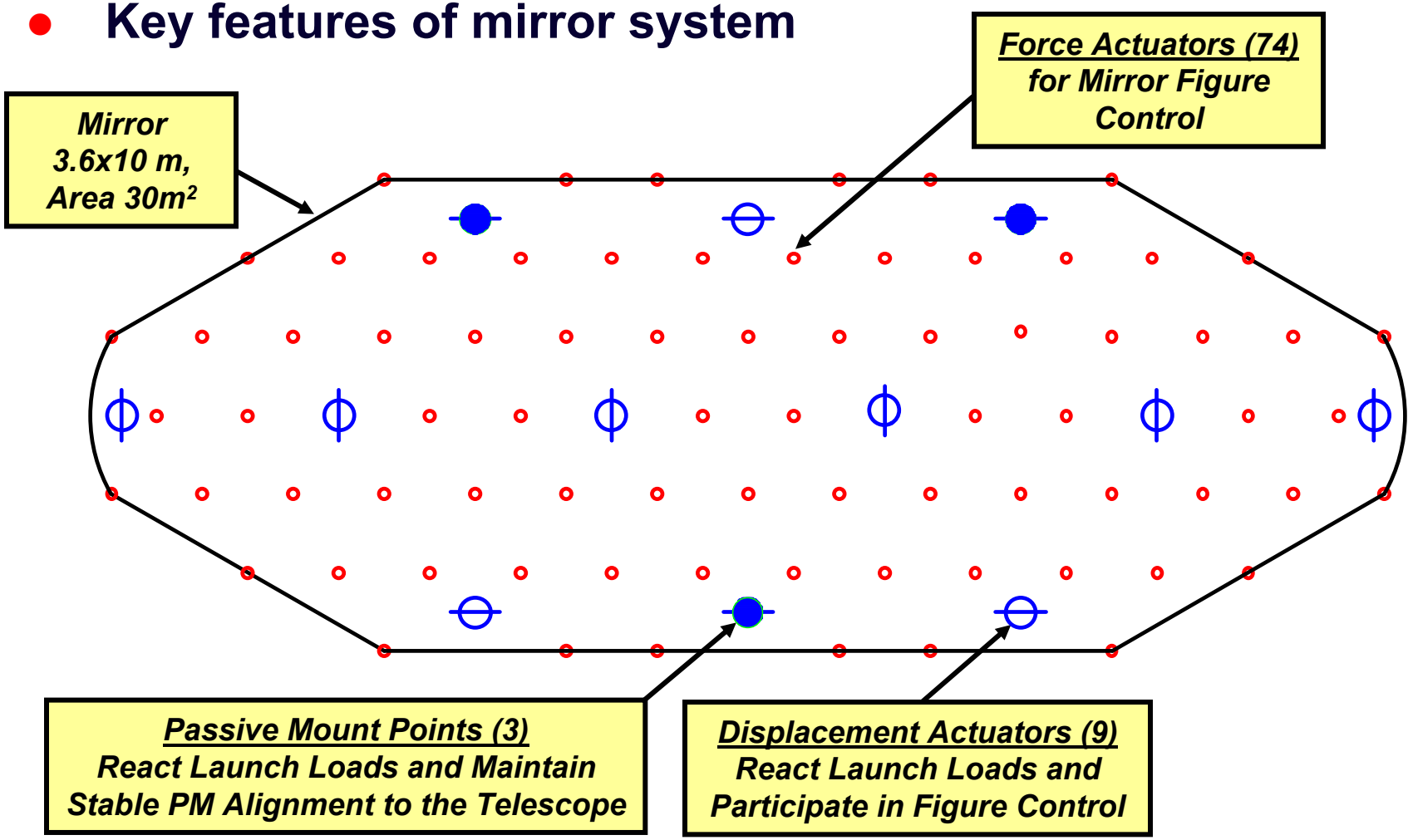
Mirror System Concept

- **Key features of mirror system**



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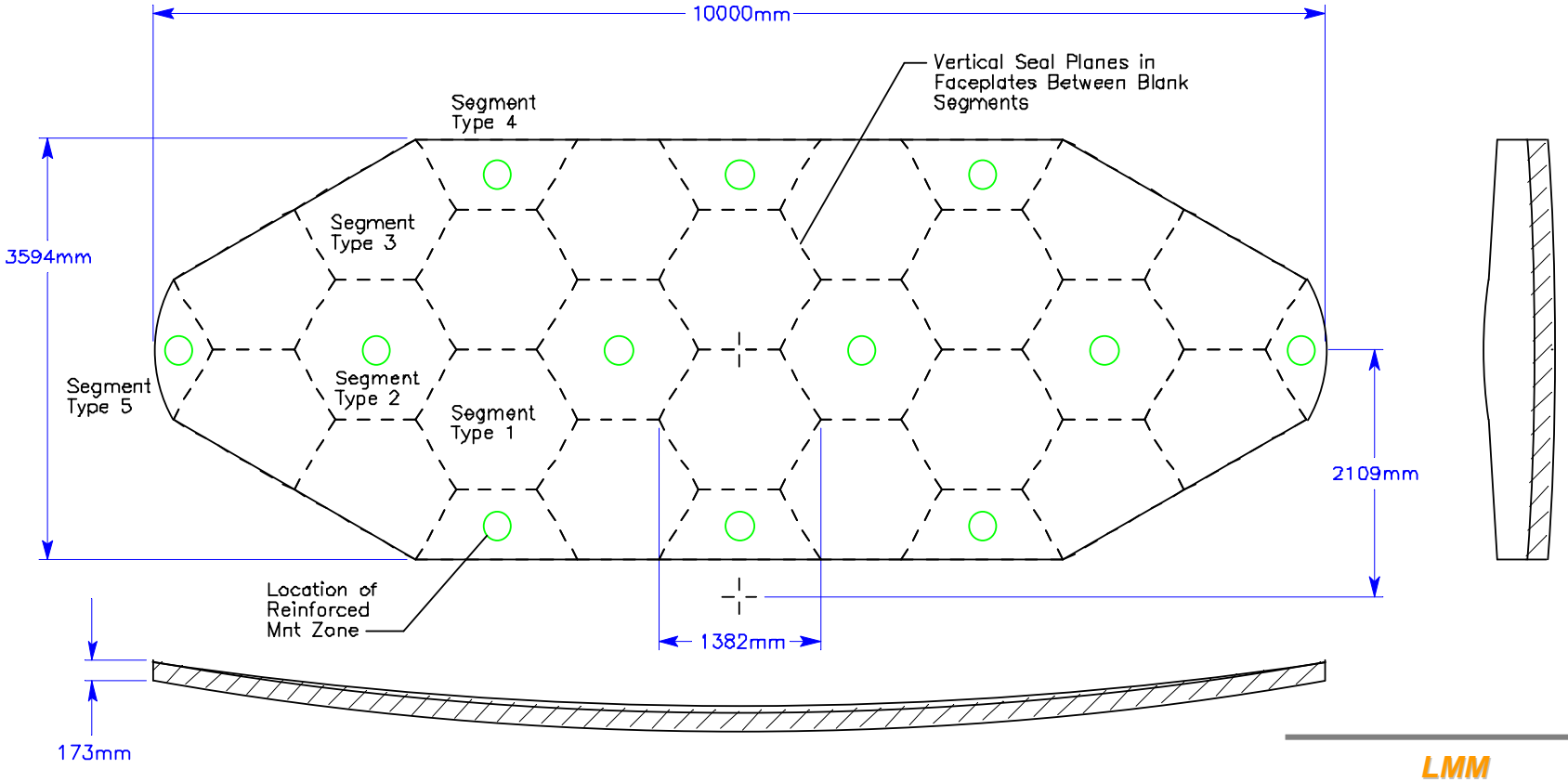
Mirror Concept

- **Mirror is assembled from 30 smaller lightweight blanks constructed from Corning ULE™ glass**
  - Blanks are joined by edge welding faceplates before processing



LMM

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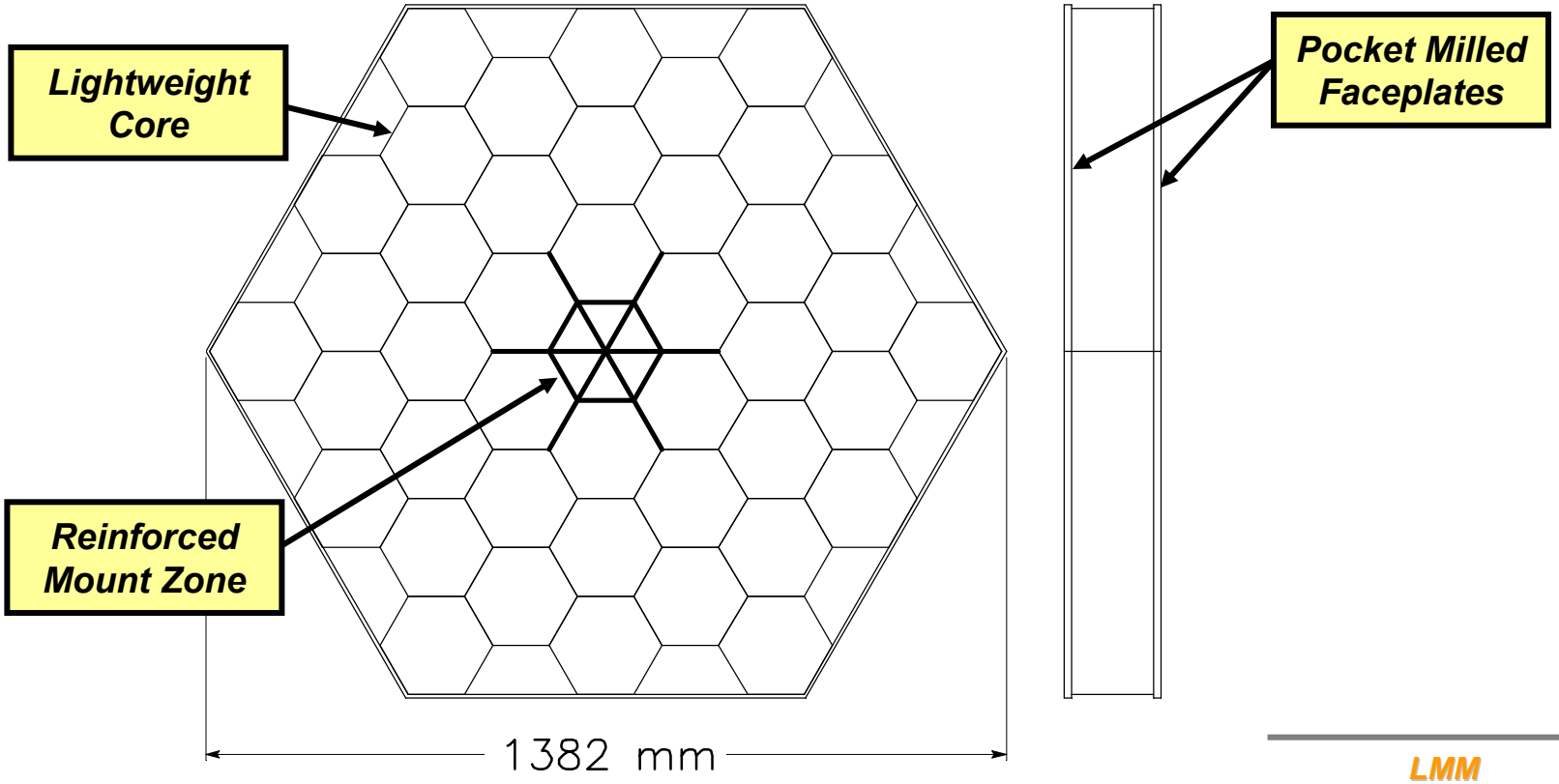
Component Mirror Blank

- **Each small plano lightweight mirror blank is fabricated and fully inspected prior to edge welding into large mirror**
  - Substantially reduces fabrication risk and facilitization for fusion



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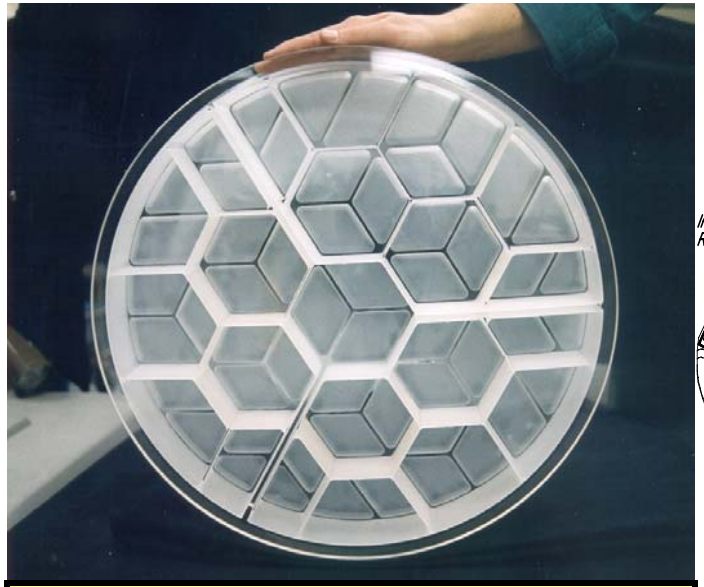
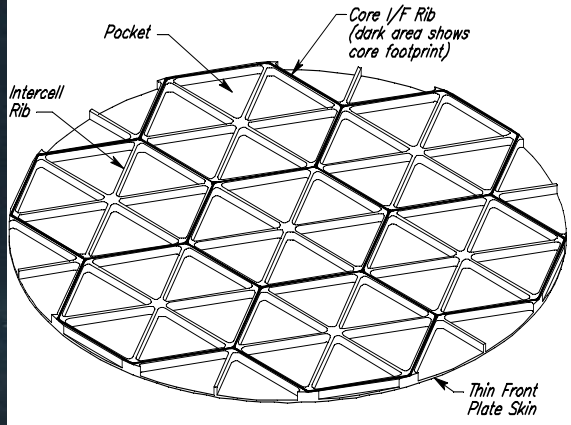
Faceplate Pocket Milling

- **Front and back faceplates are pocket milled to reduce mirror mass while maintaining optical performance**



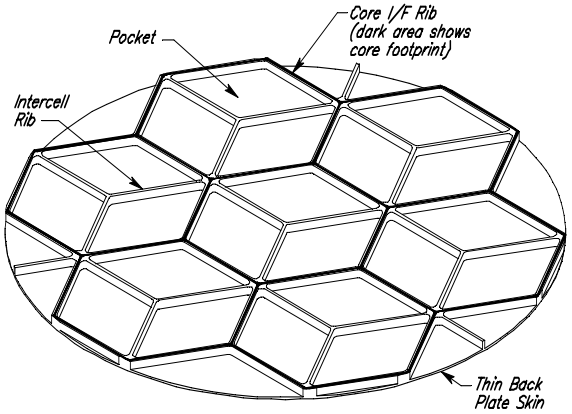
Pocket Milled Demonstration Mirror (Includes a Segmented Core)

FP Pocket Milling: 6 Ribs Per Cell



Section of Pocket Milled Front Plate (Isometric View)

BP Pocket Milling: 3 Ribs Per Cell



Section of Pocket Milled Back Plate (Isometric View)

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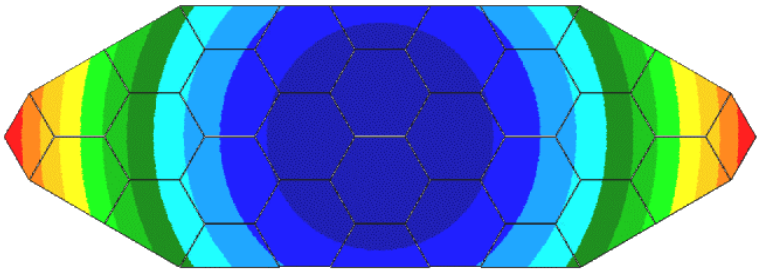
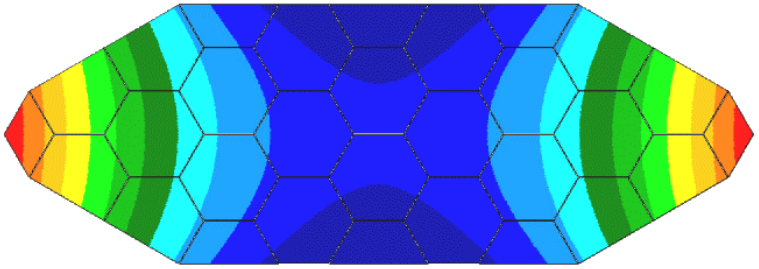
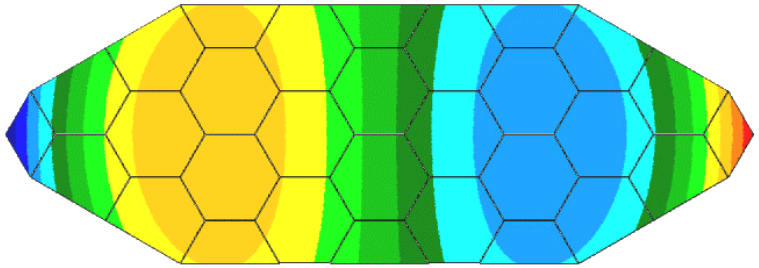
Figure Correction: Low Freq Errors

- **Actuators efficiently correct low frequency figure errors**

Input Surfaces, No Correction







Power	Force/Displ Acts	% Correction
	18/9	97.4
	56/9	99.5
	74/9	99.6

Actuator Quantity

% Actuator Correction

$$1 - \frac{\text{Corrected Surface RMS}}{\text{Input Surface RMS}}$$

Astigmatism	Force/Displ Acts	% Correction
	18/9	98.8
	56/9	99.5
	74/9	99.6

Coma	Force/Displ Acts	% Correction
	18/9	94.0
	56/9	98.1
	74/9	98.5

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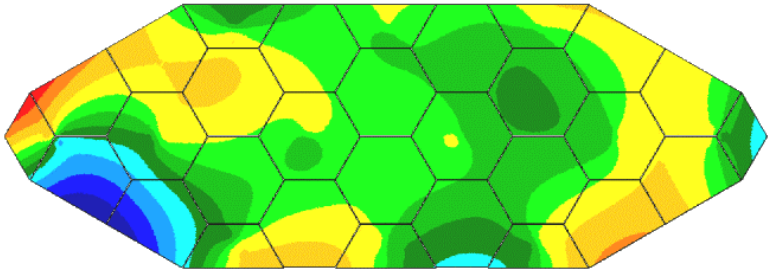
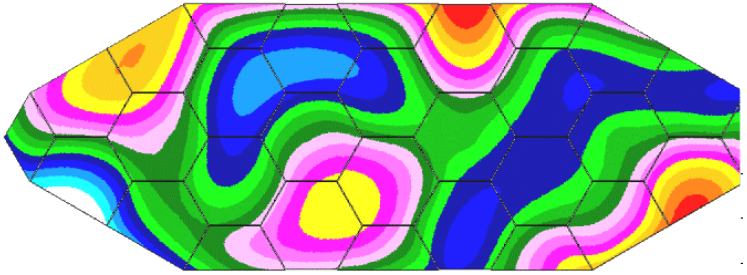
Figure Correction: Mount Strain and Thermal Errors

- **Actuators also correct mount strain and thermal errors**
  - The quantity of 74 force actuators was selected based on correction of thermal & mount strain errors

Input Surfaces, No Correction



Random Unit Moments at Each Mount/ Displ Actuator	Force/Displ Acts	% Correction
	18/9	73.2
	56/9	85.0
	74/9	85.5



Random CTE Variations Seg-to-Seg & Front-to-Back	Force/Displ Acts	% Correction
	18/9	77.7
	56/9	82.4
	74/9	92.2

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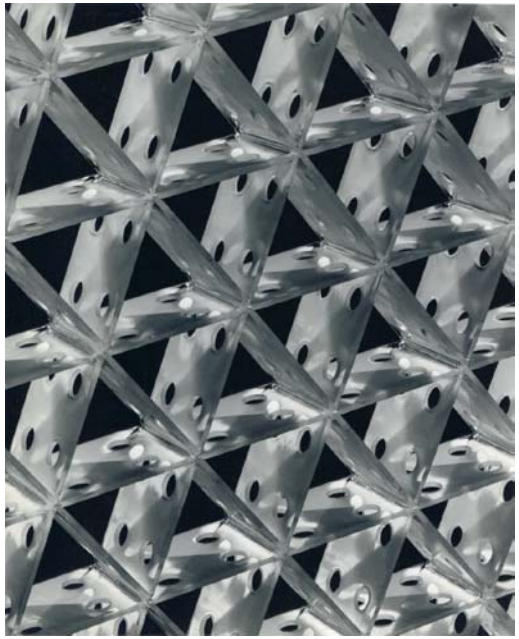
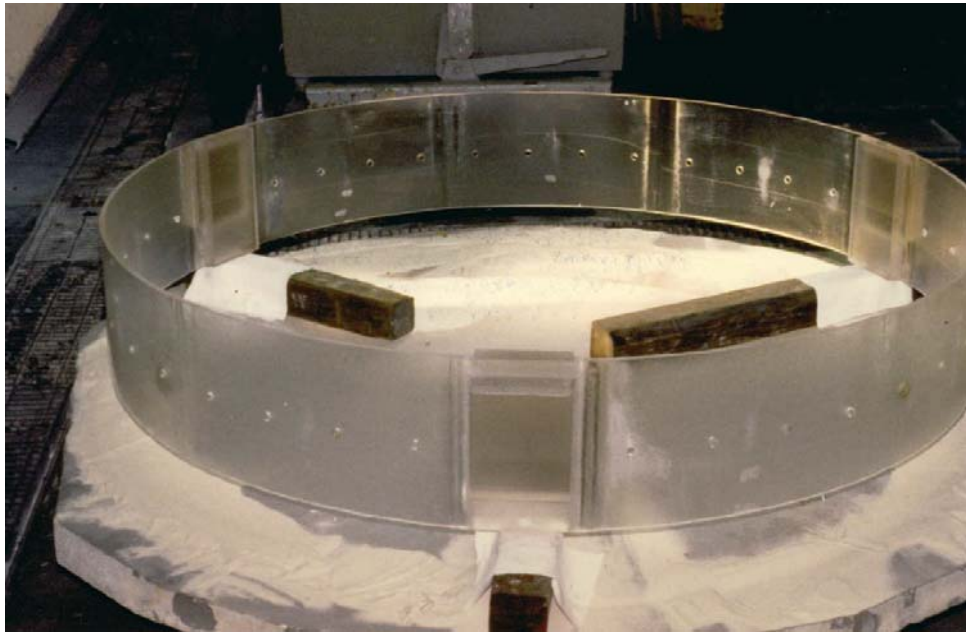
Edge Welding of ULE™ Glass

- **Edge welding lightweight ULE™ blanks is a key LMM technology**
  - Corning has a long history of welding ULE™ glass into various shapes
  - Edge welding lightweight blanks for LMM is an extension of existing methods



Fusion Welded ULE™ Mirror Core



Large Fusion Welded ULE™ Mirror Edge Ring

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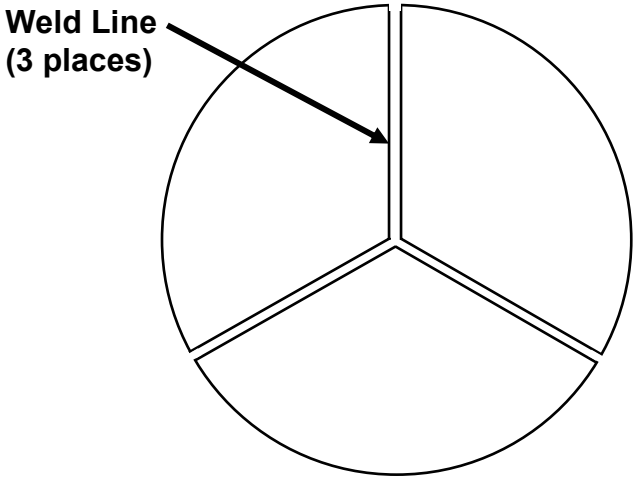
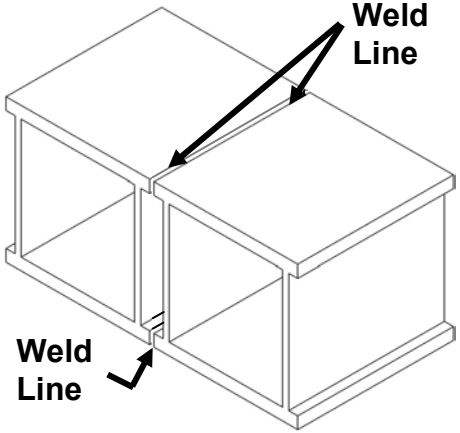
Edge Welding Demonstrations

- **Corning is fabricating edge welded test samples for Kodak evaluation under a current NRA study**
  - Samples will be processed at Kodak to evaluate optical finishing across welds and optical performance of seams in welded mirrors



Solid 230mm Edge Welded Demo Mirror



Lightweight Edge Welded Demo Blank

Subscale Demo Mirror Design

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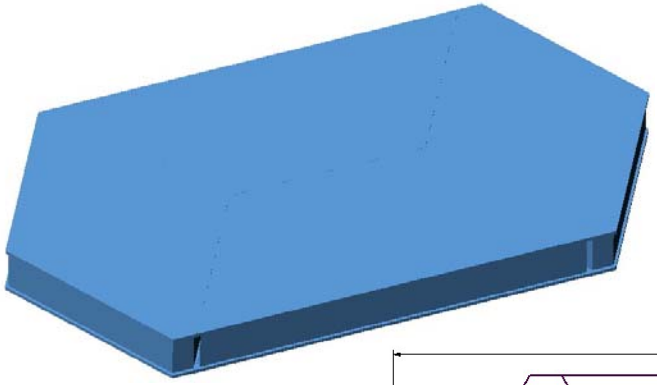
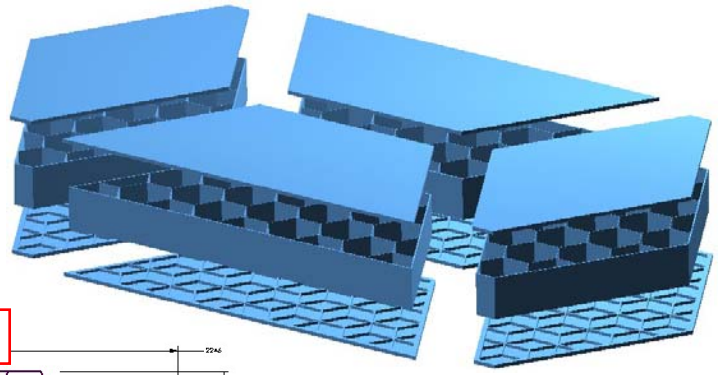
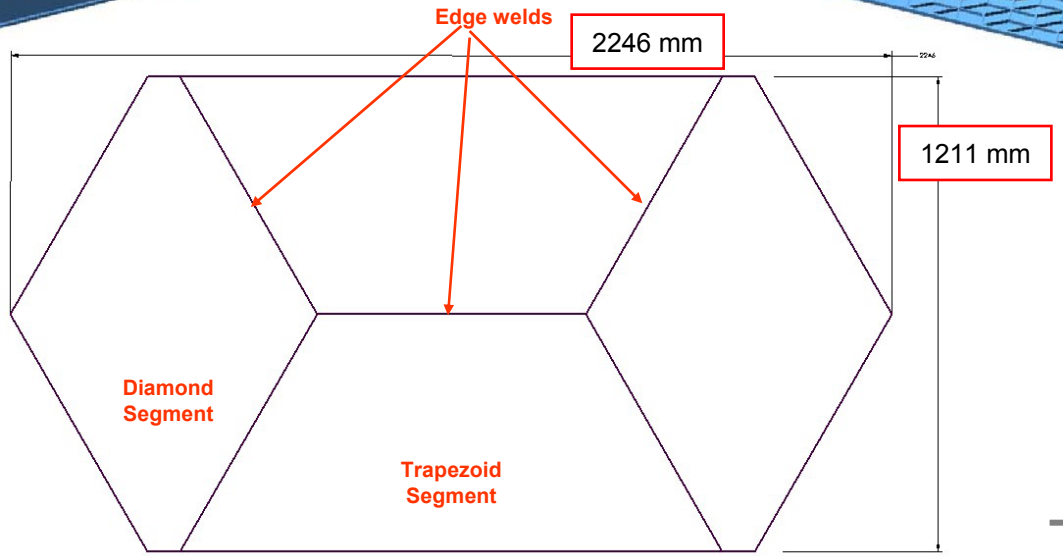
- **The subscale demo design maintains the challenges of the full size mirror while fitting within existing facilities**
  - Design features include 4 edge welded segments, pocket-milled front and back plates, an off-axis asphere







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Summary

- **Kodak has developed a concept for a 4x10 meter mirror for TPF which builds on successful experience with many of the key technologies**
  - Active figure control of a semi-rigid mirror
  - Segmented mirror cores
  - Low temperature fusion (LTF)
  - High temperature fusion/welding
  - Low temperature slump (LTS)
  - Polishing and testing of lightweight mirrors to achieve excellent midspatial figure performance

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Summary (cont'd)

- **Several key LMM technical challenges have been identified**
  - Mirror mounting
  - Edge fusion/welding of mirror blank segments
  - Optical metrology
- **A subscale mirror has been designed to demonstrate many of the key technologies**
  - The 1.21 x 2.25 meter mirror can be fabricated using existing facilities
- **Edge welding small blanks into a large blank substantially reduces blank fabrication risk and facilitization**
  - Processing and optical test results from the current edge welded samples will be reported in mid October '03
- ***The concept of building a 4x10 meter mirror for TPF appears to be feasible***